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OUR DEBT TO ASTRONOMY.

BY RUSSELL TRACY CRAWFORD.

Astronomers are so often asked questions such as "What is astronomy good for?" "Why waste your time and energy upon anything so immaterial and unpractical as astronomy?" "What good does it do to know where a comet is going?" etc., that it seems opportune and fitting to answer such questions quite thoroughly. For this reason the subject "Our Debt to Astronomy" has been chosen for this address. These questions and many others of a similar nature show how little thought is given by the general public to such matters, and how carried away they are with the intensely practical ideas of this rapidly advancing age, which seems to have emblazoned upon its banner not "Excelsior," but a glaring monogram of the United States with the curve at the bottom of the U eliminated from the picture. Among other things I hope to convince the followers of this banner of the almighty dollar that astronomy is one of its most potent aids and should therefore be one of its pets, worthy of its support.

Upon this subject Professor YOUNG writes as follows in the introduction to his "General Astronomy":—

> "At present the end and object of astronomical study is chiefly knowledge pure and simple; so far as now appears, its development has less direct bearing upon material interests of mankind than that of any other of the natural sciences. It is not likely that great inventions and new arts will grow out of its laws and principles, such as are continually arising from physical, chemical, and biological discoveries, though of course it would be rash to say that such outgrowths are impossible. But the student of astronomy must expect his chief profit to be intellectual, in the widening of the range of thought and conception, in the pleasure attending the discovery of simple law working out the most complicated results, in the delight over the beauty and order revealed by the telescope in systems otherwise invisible, in the

recognition of the essential unity of the material universe, and of the kinship between his own mind and the infinite Reason that formed all things and is immanent in them. . . .

"At the same time it should be said at once that, even from the lowest point of view, astronomy is far from a useless science. The art of navigation depends for its very possibility upon astronomical prediction. Take away from mankind their almanacs, sextants, and chronometers, and commerce by sea would practically stop. The science also has important applications in the survey of extended regions of the country, and the establishment of boundaries, to say nothing of the accurate determination of time and the arrangement of the calendar."

It is the intention here to go further than this, and to speak not only of the present, as Professor YOUNG does, but to go back to the beginning of things and to show the principal accounts in "Our Debt to Astronomy."

Let it be known at the outset that for many centuries, from the beginning of terrestrial affairs, the history of the world is practically the history of astronomy. For many centuries, we cannot say just how many, astronomy was the one and only agent to quicken the thoughts of men and to lead them to a comparatively high state of intellectual development. Place ourselves, if we can, in imagination back into the so-called prehistoric times, and it will at once be evident that the most striking phenomenon of nature—viz., the rising of the Sun, Moon, and stars in the east, their daily journeys across the sky, and their setting in the west—would be the first thing to draw thought and set active minds to speculate. Once started, the keen mind would soon find other phenomena of astronomy to work upon, and in this way was built up that foundation for the superstructure of culture and knowledge which we find in the possession of earliest historical man—our first debt to astronomy.

We find that, in the beginning of what we may call authentic history, astronomy was purely a practical science. Theoretical astronomy there was, wild as it may have been, but it was the practical side of astronomy that was most developed and cultivated. It was very necessary in those times, when agriculture was the main industry, to know when to sow the crops, and when to reap them,—in other words, a knowledge of the season was essential to existence itself. And how, indeed, was a knowledge of the seasons to be had, not only then but now, except by a careful study of the wanderings of the Sun from its southernmost position to its most northern station, and back again, during the course of the interval of time that we call a year? Let us consider, in particular, the case of the Egyptians. Egyptian civilization would have been impossible but for the Nile floods, which appear with great regularity. The rising waters reach the region of Heliopolis and Memphis almost exactly upon the day that the Sun is at the summer solstice. It is very evident, then, that the Egyptians before us were under obligations to the astronomers of their age to inform them of the time when the Sun would be at the summer solstice. It is no wonder, then, that the Egyptians commissioned their astronomer-priests to observe carefully for the helical rising of *Sothis* or, as we now call it, *Sirius,* the dog-star, to give them the necessary datum upon which their year's material prosperity depended. As every advance in early knowledge and civilization was an essential stepping-stone to our present acropolis of culture, we of to-day owe this a second debt to astronomy.

It must ever be borne in mind that our present-day knowledge has not been attained by the spontaneous outburst of genius in a single generation, but has been built up slowly, step by step, from earliest times, each single advance being a necessary precursor of later development. HIPPARCHUS must precede PTOLEMY, and PTOLEMY must precede COPERNICUS. COPERNICUS made the way easier for KEPLER, and KEPLER in turn added the stone upon which NEWTON built, and so on. To every contributor of a stone in our Temple of Knowledge, whether it be in foundation or superstructure, we of to-day owe a debt.

Incidentally, we have a decided personal interest in the theoretical astronomy of the Babylonians, who gave us the week of seven days, with the names taken from the Sun, Moon, and the then-known five planets, *Mercury, Venus, Mars, Jupiter,* and *Saturn.* Had *Uranus* and *Neptune* been known to them, our week would have been nine days long instead of seven, with one day in nine for rest.

To astronomers and their science we owe the evolution of the ideas and conceptions of the size and shape of our globe. The earliest peoples believed the evidence of the senses, and thought that they lived upon a large flat surface. More advanced ideas were that the Earth was a truncated cone, and then a cylinder, and finally, even so early as the time of PYTHAGORAS, it was shown to be a sphere. As to its size no definite conception was had until comparatively recent times. The determination of its dimensions to-day would be impossible but for the astronomer.

Astronomy has not always advanced, but has had its setbacks, from which, however, it has nobly recovered. This brings me to speak of the retarding influence of ARISTOTLE and PTOLEMY upon the world's knowledge and culture; its overthrow brought about by astronomers, and the wonderful results therefrom—one of the greatest of our debts to astronomy.

In the third century B. C. ARISTARCHUS of Samos and others of less note had asserted that the Earth was in motion—a very advanced idea for the time; but they could not prove it. Then came a backward step, taken by PTOLEMY, who apparently proved that the Earth was not in motion, but was immovable at the center of the universe. This idea held sway for fourteen centuries, until the time of COPERNICUS. Its overthrow came at about the time of the downfall of the influence of ARISTOTLE. These two accomplishments were the most vital forces of the Revival of Learning. It has well been said that ARISTOTLE retarded the progress of the world's knowledge and culture more than any other one man. His dictum was the undisputed law in the realms of knowledge for seventeen centuries. If any one dared to present an idea contrary to ARISTOTLE the sneering question was ever ready, "Do you think you know more than ARISTOTLE?" and the investigator was completely squelched. This absolute servility to the dogma laid down by the great philosopher furnishes one of the most remarkable pictures in history. But sooner or later this had to end, and the end came with GALILEO, the astronomer. I may recount here the beginning of this end. ARISTOTLE had said that a large heavy body would fall from a given height in less time than a small light one. For seventeen centuries it had never occurred to any one to investigate experimentally the truth of this assertion, or else no one had dared to try it. GALILEO, the astronomer, however, was not content to take the word of anybody, even ARISTOTLE, upon a matter which could be proved or disproved so easily as this.

one. Dramatic indeed must have been the scene when the great astronomer mounted to the top of the leaning tower of Pisa and let fall simultaneously a large heavy body and a small light one, and great indeed must have been the astonishment of the populace gathered to witness the experiment when they beheld the two bodies falling side by side and reaching the Earth at practically the same time, demonstrating, as KIPLING puts it, that "heart-breaking power, the perversity of inanimate things." At that instant fell also the influence of ARISTOTLE in the scientific world.

COPERNICUS had just previously shown that the Earth is in motion about the Sun, and when GALILEO clinched this idea, so to speak, by turning his telescope upon *Jupiter* and there beholding the four moons revolving about the central mass, a miniature world, the revolution was complete. It is difficult for us to imagine what a convulsion must have taken place in the minds of men at that time. The Church had taught that the Earth was stationary, and even to think anything else was the greatest heresy, as it was contrary to Holy Writ. In view of this, is it any wonder that we had the Dark Ages? Because of the unswerving adhesion to dogma in those days it is, again, no wonder that the great astronomer, GALILEO, was brought before the Inquisition, tried and convicted of heresy, furnishing one of the most dramatic, almost tragic, incidents in the history of science. But the ideas once started by COPERNICUS and GALILEO soon began to spread and found firm supporters, and the world once more started on the way of progress. We cannot begin to appreciate the effects of such a revolution in the world's thought. At first sight one would say, "What a loss of importance and dignity!" We are no longer the great IT,—the center of the universe about which all else must turn, and to which all else must be subservient. But, on second thought, we would say, and do now say, "What a gain in beauty and grandeur!" We now find ourselves whirling about the great Sun in the infinite sea of ether, gazing into its immeasurable expanse. Can any one estimate the amount of dollars and cents in this debt we owe to astronomy? No; it is above dollars and cents.

Following quickly upon the steps of these two great astronomers we have KEPLER, who gave us his laws of planetary motion, by means of one of which the scientific mind was freed from the so-called perfect path, the circle, and was introduced to the use of the general conic. His work, in turn, formed the stone upon which Sir ISAAC NEWTON built so well. It would be a long story, indeed, to recount the various debts we owe to this man, our greatest astronomer. For the more practical-minded, however, I will call attention merely to one of his accomplishments. In evolving his universal law of gravitation, and in furtherance of his astronomical investigations, it became necessary for him to invent a new branch of mathematics—namely, Calculus. Is there any one so daring as to estimate the commercial value of calculus? The idea is staggering. It is beyond human power to make the computation. Without this powerful implement, due to astronomy, what could be done in applied mechanics? Where would our sky-scrapers be? How could we build our battleships? Where would our electric-cars be? How could our enormous bridges be built?—and so on, almost *ad infinitum.*

Less than a month ago, while coming in from Oakland on the electric-car, a friend asked me the old question, in rather inelegant English, "What is astronomy good for?" Among other things I said, "I suppose you see no connection between astronomy and this electric-car?" The answer was a ready "No!" The connecting-link is this same calculus.

We find, not only in the applied sciences, but also in many of the natural sciences, higher mathematics to be an absolute necessity. And to what are the higher branches of mathematics due? The answer is, "Principally to astronomy." I wish to quote here from Dr. WILLIAM F. WHITE'S article on "The Nature of Mathematical Reasoning," in No. 609 of "The Open Court." He says, "Behind the artisan is a chemist, behind the chemist a physicist, behind the physicist a mathematician." There he stops, but I now add, behind the mathematician the astronomer.

Another great debt that we owe to astronomy is one on behalf of our peace of mind. From the beginning up to the present time there have been, and now are, many people filled with superstition concerning the heavenly bodies. Thanks to astronomy, these are becoming fewer and fewer. In ancient times whole nations were thrown into a panic by an eclipse of the Sun; armies on the eve of battle were commanded to halt, with disastrous results, to await the passing of the illomen of an eclipse of the Moon. Comets were supposed to be within our own atmosphere, and to bring pestilence and disease. These phenomena have been shown by astronomers to be ordinary affairs in the celestial mechanism, having no bearing upon our regular existence. Unusual conjunctions of several planets are even now by some thought to have an important bearing upon the affairs of life. Many crafty people to-day make a livelihood by imposing upon the more superstitious and easily-fooled people by casting horoscopes. One of our daily papers thinks so little of the value of its space as to give up a quarter of a column in every issue to the publication of COZETTE'S horoscope for the next day.

Within the last few weeks the papers announced that a comet had been discovered by an astronomer on Mt. Ætna, which was coming directly toward us and would soon annihilate the Earth. Immediately after the appearance of this wonderful announcement this observatory had many letters of inquiry concerning it. Some people evidently believed in it, and wanted to know the exact date when the direful catastrophe would occur. Probably there will always be some who will be thus taken in, but, thanks to the teachings of astronomy, we live in practically perfect peace of mind regarding these things. Nations are no longer convulsed by an unexpected eclipse, and astronomers royal are not decapitated for failure to predict them.

A study of the simple elements of astronomy would be very beneficial to artists and writers. They often make serious mistakes through mere ignorance. It is not very uncommon to see an otherwise beautiful painting spoiled completely by a delicate crescent Moon with its horns pointing toward the Sun. A note in No. 383 of the *Observatory* calls attention to the fact that in chapter I of "Jane Eyre," by CHARLOTTE BRONTÉ, occurs this expression: "(The Moon's) newly risen crescent, attesting the hour of eventide," a statement which makes the author appear ridiculous. Many instances of this kind could be cited.

Finally we come back to Professor YOUNG'S statement, to consider the present-day, all-absorbing, dollars-and-cents value of astronomy. You have all probably traveled at night, resting more or less comfortably in a berth of a Pullman attached to an express train, which in its course thunders by a freight train on a siding. You give but little, if any, thought to it, having confidence in the men running the train. These men in turn have confidence in their running because they are running "on time." Think what it means to the railroads of the country, and to the public, to have the trains running "on time." To be able to handle the enormous traffic of to-day correct time is an absolute necessity. Where do the railroads get their correct time? Another account in our debt to astronomy.

Again, when it became necessary to run the boundary-line between Canada and the United States astronomers had to be employed. Our maps cannot be made without a knowledge of practical astronomy. Extended surveys also require a knowledge of practical astronomy.

I will call attention to one more, perhaps the greatest, commercial debt we owe to astronomy; that is, the service it renders to navigation. Were it not for the data furnished by astronomers, commerce by sea would practically stop. The sailing-master on the high seas could not determine his position, nor in what direction to head his ship in order to reach a desired harbor. Think what this means in dollars and cents, and estimate it if you can. For this one service alone the science of astronomy is worth more in dollars and cents to the world in one week than has been expended upon it since the beginning of civilization. Do you think that Great Britain, for instance, would take in exchange an amount equal to its national debt for what astronomy gives her? I answer for you, most emphatically, "No."

Even these commercial values sink into insignificance when we consider again, in general, what astronomy has done for us in giving us the laws upon which mechanics is based; in pushing mathematics to its present state of development, the effect of which ramifies rapidly; in being one of the most powerful factors in bringing us to a better understanding of nature; and in broadening our views and taking us out of the narrow confines of a little plain, immediately surrounding the Ægean Sea, and launching us into the infinite realms of space.

In conclusion, I wish to answer one more question—namely, "While some parts of astronomy may be of value, why exert so much thought and energy upon other parts which are purely abstract and theoretical?" The answer to this is that we never can tell to what such abstract speculations may lead, and that, in the end, they may give us something exceedingly valuable, either in the commercial world or in the realms of culture and knowledge. A comparison with prospecting may make it clearer. The miner digs day after day with apparently no return. He may continue to do so with no result, no matter how long he labors; but, on the other hand, at any moment he may unearth a rich vein which will more than repay him for his efforts. So it was with KEPLER, when he dug through TYCHO's observations day after day with no result, until finally, after much labor and the use of an enormous store of patience, he struck the vein of planetary motion, and his wonderful laws were brought to light. It was MICHAEL FARADAY who said so well, "There is nothing so prolific in utilities as abstractions."

And now, in closing, I desire to express the hope that you who have heard what I have had to say, and those who may hereafter read what I have said, will ever feel it unnecessary to ask in inelegant English, "What is astronomy good for?"

BERKELEY ASTRONOMICAL DEPARTMENT, July 13, 1907.

THE LOST RINGS OF *SATURN*.

By ARTHUR B. TURNER.

The Moon long since became a dead world, without air or water. The planet upon which we dwell is well advanced in its development; its surface has cooled and hardened, but it still has air and water, the great life-giving elements. We look out upon the planet *Mars* with its surface covered by canals in the struggle of the inhabitants to get water to supply their needs. But beyond *Mars*, at a distance more than nine times our distance from the Sun, there circles a world, resplendent in the making, surrounded by satellites and rings, and taking over twenty-nine years to make its majestic swing around the Sun. This orbit formed the boundary to the solar system down to the discovery of *Uranus*, by HERSCHEL, in 1781. *Saturn* has a diameter a little more than nine times that of the Earth, and makes over two revolutions on its axis in one of our days. The result of such swift rotation is to make